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22 October 2012

City of Saco, ME
300 Main Street
Saco, ME 04072

Attention: Angela Blanchette

Reference: Stackpole Creek Bridge, Saco

Dear Angela:

On 25 July, 13 August, and 8 September 2012 I visited the Stackpole Creek Bridge in Saco to make visual observations regarding its deteriorated structural condition. This included exterior visual inspection, a limited amount of probing, and rough measurements to ascertain the overall geometry of the bridge and aspects of its present physical state.

We have also reviewed conditions reports produced by DeGrunchy Masonry of Quakertown, PA and CLD Associates of York, ME. These reports offered conclusions as to the causes of the deterioration and proposals for its rehabilitation or replacement.

The following is a summary of our thoughts and opinions regarding the conditions reports and associated recommendations, conditions we have noted in the field, and our own recommendations for repair.

<u>General Description and Historical Construction</u>

The Stackpole Creek Bridge was constructed in 1848 to provide a new crossing over the Stackpole Creek on Simpson Road in northern Saco. The creek flows into the Saco River from the north, crossing under Simpson Road, which we will consider to run east-west. This crossing takes place where the riverbed consists of a steep-sided ravine that is subject to significant seasonal variations in flow.

Historical Construction-

The Simpson Road crossing consists primarily of a dry-laid stone sided earthen embankment with a small, arched tunnel-like portal through which the creek flows. The entire structure is approximately 110-feet long by 26-feet wide at the top by a maximum of about 24-feet high. There is one 7-foot wide by 18-foot tall arch span in the center.

Based upon our visual observations, test pits, and probes, we determined that the structure consists of entirely dry-laid stone masonry with mortar pointing on the exterior, which retains an earthen and rubble core of unknown volume and geometry. This was probably constructed in the following way:

- Solid, square-edged broken stone granite footings were laid directly on the bedrock that lines the bottom of the riverbed Then, a combination of square-edged and angular broken granite blocks were laid in an interwoven, but un-coursed, manner over them, creating the vertical walls that form the waterway and the slightly battered sides of the approaches. By viewing into open joints and cavities within the structure, it appears that the interwoven wall construction is at least 8-feet thick (the farthest one can see) at the base and thinner toward the top. The angular and interwoven nature of these stones give the walls stability and strength, as the heavy rough-cut stones bear solidly on each other at wide parallel planes and the roughness of their bearing surfaces give them good resistance to shear.

- Once the walls had risen to sufficient height, random field stone cobbles were laid into the enclosed space to act as free-draining fill and to support the eventual roadway above. Based upon our observations, the stones that make-up this internal fill are mostly rounded in nature, and have very little resistance to shear as their combined mass is analogous to a box of marbles – stable and strong if the box is closed, unstable if the box is opened.

- As the structure reached a height of about 15-feet above the riverbed, arched wooden forms were constructed between the abutment walls to support the construction of the single wythe rough-cut stone arch that spans 7-feet over the riverbed. The walls and arches were chinked, the sidewalls extended up over them, and then the fieldstone cobble fill was placed over the arches and between the sidewalls to create the sub-base for the roadway.

- Various gradings of earth would have been placed over the cobble fill, perhaps starting with rough stoney gravel that would span the voids between the cobbles and then finer and finer gradations until a sift-resistant road surface was created. Alternatively, a clay layer may have been inserted to prevent sifting of the road fill.

- Side guards were created by drilling holes in the top stone course of the sidewalls and inserting used or surplus carriage axles, which then supported wooden fence rails and/or the present cables.

- The roadway was later asphalt paved, which has been the wearing surface of choice up through present times.

Unusual Configuration and Geometry-

If one compares the cross-sectional area of the portal to that of the riverbed, the ratio is less than 20 percent. This means that the crossing creates a significant choke point that can back up the river's flow at a time when contemporaneous structures were frequently built with longer and even multiple spans requiring less material to be brought in to construct the approaches. It almost seems as if the intent was to create something that would even out the river flows downstream by damming up the stream.

Historical experience demonstrates this to be the case, as there have been documented occurrences when the creek has been backed up to the point of over-topping the structure.

The question is, then, why would people who lived locally, and had theoretically experienced the flows of Stackpole Creek firsthand, have gone to extra effort to build a structure that was so seemingly inadequate for passing the flows. Could the damming effect have been an intentional effort to reduce the peak flows on the downstream side of the crossing, or it just the collateral effect of the builder's error in judgment?

Beyond its questionable functioning as a bridge, the bridge also presents a choke point in the Simpson Road, as traffic has been reduced to a single lane in order to accommodate proper guard rails that are embedded in the soil embankment several feet in-board of the stone sidewalls.

Present-Day Conditions

Between our first and second visits to the site, we reviewed previous reports and documentation provided to us by the city. These included a 2007 report by DeGrunchy Masonry, of Quakertown, PA and a 2011 report by CLD Associates of York, ME.

Observations by DeGrunchy

From our review of DeGrunchy Masonry's report we found it to have a general bent toward preservation of the structure, as even stated in the text. This report describes the results of DeGrunchy's site visit, describes their concerns, and makes recommendations for repairs, including hand sketches and a supplemental report by a Structural Engineer in the UK.

DeGrunchy states in their report that:

> "…*the main threat to the structure is not from road traffic but the possibility of the creek getting dammed up and water levels rising such as to encourage a major erosive flow over the top and past the ends of the masonry structure where the thinner layers of infill would get stripped away first followed by the formation of swirlholes and surges to strip out the soil infills. In theory, the stone structure would begin to tumble as the chink stones and smaller stones become loosened by water and gravity acting on the off-center weights*."

While we disagree that road traffic is not the main threat to the bridge, we concur with DeGrunchy's concern as to washing away of the structure from erosion. DeGrunchy also states that:

> "*The complete masonry structure has demonstrated many times that it has an adequate mass and frictional stability to safely resist the very high flood levels which have been recorded*".

This is in keeping with our own impression as well, having completed some preliminary calculations that find the road embankment structure to be laterally stable with water retained for its whole height on the upstream side.

Observations by CLD

The following defficiencies were noted in the CLD report dated May 2011:

> *"Arch – At multiple locations, cracks have gotten longer and mortar loss is evident. Photos have been included to show these areas. Additional photos have been included to illustrate how gaps between stones have increased from 2003-04 to 2011.*
>
> *Gauge readings indicate that the upstream third of the arch continues to move outwards.*

We believe that the primary force that is driving this transverse arch spreading is the dragging effect of the sloughing fill that surrounds, and is also spreading, the walls. We have done an analysis of the embankment as a retained soil structure, and found that that the greatest spreading force on the side walls is not the dead weight of the fill or fluid pressure of retained water, which is theoretically drained, but from truck wheel loads. Because of the rounded nature of the fill, approximately 36 percent of any downward force on the roadway is translated as a lateral force in the embankment.

> *"Roadway – Cracks are clearly visible in the pavement overlay that was placed in September 2009. These cracks generally follow the same pattern that was evident in the previous pavement surface. City personnel noted that two small depressions (starter sinkholes) had developed behind the jersey barriers, just prior to the onset of snow cover. Curbing and drainage appear to be performing as intended.*

Having witnessed the same or similar cracks, we suspect these have been caused by the transverse spreading of the structure. Rainwater seeps in through these cracks in the pavement and washes the fine sub-base fill materials down into the voided cobble fill below, creating sink holes.

> *"Steel Bracing – Surface rust covers all of the steel members, and the whalers (more so than the columns or tube sections) have begun to delaminate with notable section loss. This bracing was installed in December 2001 and at that time was considered to be a temporary stabilization measure anticipated to be in place for two-years."*

The above observations, which coincide with our own, suggest that the steel frame is nearing the end of its life.

Two of Our Own, Additional Observations

- There are several severe bulges in the stonework on the north face of the structure, particularly at the east embankment. Stones have fallen out of the wall near the bottom, most of the way up the slope.

- The south end of bottom stone at the south edge of the east abutment wall overhangs an empty cavity below, possibly having been undermined by scouring river flow.

Proposed Repairs and Associated Costs

DeGrunchy Masonry:

DeGrunchy recommended the following in their report:

1. *Foundation underpinning to remove soft materials and filling erosion, sealing the base and void filling.*
2. *Masonry consolidation rebidding, rebuilding/realigning, stitching face-stones, pointing, grouting down back of stones, wall head protection, and tidying up the ends of the wingwalls, etc.*
3. *Excavation down to the arch springing level and grouting the joint in the arch.*
4. *From this level, installing 'Cintec type' piled support and anchors to strengthen the breastwalls and the culver general all the traffic carrying capacity to be increased.*
5. *Flood control overflow system and spillway*
6. *Re-leveling and redoing road surface and water control and drainage.*
7. *Safety rails, etc.*
8. *Footpath upgrade.*
9. *Vegetation control.*

Estimated Cost = $593,000 per DeGrunchy ($721,000 in $/2012)

We estimate that the work described under this scheme would cost $880,000.

The DeGrunchy proposal is rational way of restoring the structure, however the use of hydraulic lime-based products as described in their commentary is not necessarily appropriate here in a repeatedly wet, water-flow environment where the lime can break down (I discussed this with Andy when I saw him at a conference in Charleston, SC, last week).

We agree that some underpinning (1) may be needed to provide a more stable base for the abutment walls, however we do not agree (also 1) that voids should be filled within the internal core. For reasons previously stated, and from our studies, establishing an overflow spillway would be a nice benefit, but would require dismantling of more than a third of the total structure's length.

The primary element that this scheme lacks is relieving the structure of roadway loads, which we believe is a critical, although costly component to add.

CLD Consulting Engineers

We have reviewed various pieces of correspondence from CLD, including monitoring logs, proposals, cost estimates, and photographs, focusing ultimately on their Final

Letter Report of 15 March 2011. This report summarized CLD's conclusions from a relative wealth of material, and presented three recommended options for the bridge along with estimated construction costs.

CLD Rehabilitation/ Alternative 1

Description taken from the text of CLD's 2011 report:

"This alternative involves excavation and replacement of the backfill soils down to the spring line of the arch and the installation of steel reinforcing dowels and rock anchors to stabilize the abutment walls. Anchors would be drilled through the existing wing stones and into the backside of the abutment wall and the opposing wing, pinning the walls together. Reinforcing dowels would be drilled and grouted through the abutment base course stones into the underlying bedrock to provide reinforcement against wall sliding. Additional rehabilitation measures would include the following:

1. *Cast a two-way reinforced concrete slab over the backside of the arch stones to prevent further movement and to assist with load distribution in the arch;*

2. *Install a buried drainage system to collect water from behind the wingwalls;*

3. *Construct a concrete training wall extending from the northwest corner of the waterway opening to reduce the erosive effect of the swirling water pattern in this area;*

4. *Fill voids in the bottom 3+/- feet of the abutment walls with grout to stabilize the lower portion of the walls and keep water out when the creek is at its normal level;*

5. *Fill voids that are higher in the abutment walls with replacement stones, held in place with mortar on their backside where the repair would not be visible; and*

6. *Repoint/replace mortar in all exposed faces of the wings, abutments and arch barrel."*

Estimated Cost= $1,700,000 per CLD ($1,768,000 in $/2012)

We have estimated the work described would cost $1,130,000, so CLD's price for this work seems high, in our opinion.

We feel this option would be for the most part a reasonable approach for saving the existing bridge. We agree with the idea (1) of excavating down to expose the top of arch span, pinning it into the bedrock, and adding a reinforced concrete pad above it. We also agree with (3) the addition of training walls to the upstream side of the bridge as a reasonable way to increase the available flow.

We disagree, however with the idea of (4) grouting the lower 3-feet of the abutment walls, as control of the spread and consolidation of the injected grout would be very difficult, and because, according to our calculations, the structure is stable without this measure. Also, the existing structure was clearly intended to be dry-laid, and creation of uncontrolled, potentially randomly distributed grout mass could negate the free-draining advantages of the dry-laid construction.

We agree with what is essentially re-chinking (5) of the upper stonework, with or without mortar on the backsides of the stones. We agree with limited pointing (6) of the exterior surfaces, but only on the upstream, north face of the bridge where it would have the advantage of keeping impounding water from seeping into the structure. Pointing should avoided, and perhaps even removed, from the south, downstream face any water that does seep in is not entrapped. Pointing should be restored in the abutment walls and arch in order to improve stream flow and avoid internal scouring.

We also do not feel that creating a drainage system (2) behind the wingwalls is necessary, since the very nature of the dry-laid cobble fill is its own drain.

<u>CLD Rehabilitation/ Alternative 2</u>

Description taken from the text of CLD's 2011 report:

"CLD worked with CINTEC America Inc. to develop a scope and estimate to apply the ARCHTEC treatment to the arch and for stabilizing the retaining wingwalls. The CINTEC anchors are a proprietary soil anchor system with stainless steel rods in fabric socks that are filled with grout. This alternative would entail installation of anchors to stabilize the arch barrel, abutments and wingwalls. Typically, a finite element analysis for the structure is done by Gifford and Partners (U.K.) who work in partnership with CINTEC. The ARCHTEC methodology calls for a detailed survey of both the vertical walls and the arch along with testing, using both non-destructive and physical means for evaluating the geotechnical (fill and foundation).
"Alternative 2 would include the buried drainage, concrete training wall, grouting of voids, wall repointing and the repair and replacement of damaged or missing stones, that were all outlined under Alternative 1."

Estimated Cost = $1,775,000 per CLD ($<u>1,846,000</u> in 2012)

We have estimated the work described would cost $<u>1,280,000</u>. Again, CLD's price for this work seems high.

All of our comments for "Alternative 1" hold true for "Alternative 2", as CLD's recommendations are essentially the same, but with the addition of an engineered Cintec/Archtec restraining system for the arch construction.

In our opinion, longitudinal spreading and bending deflection of the arch span, which is what the Archtec system is designed for, is not the primary problem with the bridge, and therefore not something that needs to be solved.

We do concur with the use of Cintec anchors to stabilize the abutment walls, but are concerned about the prospect of using these as “soil” anchors into the cobble fill will be complicated by the extreme difficulty of drilling horizontally into the cobbles, which will shift and spin instead of being bitten into by the drill.

CLD Full Replacement/ Alternative 3:

Description taken from the text of CLD’s 2011 report:

“This option was studied to provide a cost datum to compare with the rehabilitation alternatives. The bridge type considered the most feasible as a replacement structure is a precast concrete arch with mechanically stabilized earth (MSE) wingwalls. A timber structure is also considered a feasible replacement alternative and could be combined with the same MSE walls as the precast option. Hydraulic analysis of the Stackpole Creek and backwater condition from the Saco River found that an approximate 20-ft span x 12-ft rise precast arch will provide adequate area to meet MaineDOT freeboard criteria.”

Estimated Cost (w/o aesthetic treatments) = $860,000 per CLD ($894,000 in $/2012)

We have estimated a cost of $997,000 for the work described, which is higher than CLD’s estimate.

Estimated Cost (w/ aesthetic treatments) = up to $1,160,000 per CLD ($1,206,000 in $/2012).

We have estimated a cost of up to $1,292,000 for the work described with the aesthetic treatments, which is also somewhat higher than CLD’s estimate.

While CLD has done what is in our opinion a thorough presentation of reasonable replacement options and associated costs, the main detractor is the total loss of a significant, regionally contributing and locally appreciated historic structure that could otherwise have been saved. Of the replacement schemes presented, we would from an aesthetic/historic standpoint consider the wood-timber bridge replacement the most appropriate as it does not pretend to mimic an historic structure with a modern era design.

From a functional standpoint, the replacement satisfies the need for improved stream flow, a two-lane roadway, and good-as-new (in this case new) structure.

Our Own “Hybrid” Rehabilitation Scheme

We have considered existing conditions and dynamics that surround the bridge, as well as clearly expressed local concerns over its preservation. We have reviewed the various options presented both DeGrunchy and CLD, including each proposal’s good attributes as well as drawbacks. Picking and choosing among the aspects of each scheme, we recommend that a hybrid approach be considered for rehabilitating the bridge that includes the best components of each of the proposals. We have retained the geotechnical consulting services of GEI Consultants, Winchester, MA at our own expense, to review and vet this scheme, and their input has been very helpful.

Under this plan, the lower masonry would be stabilized and restored, with the south side of the structure left unpointed to drain, most of the cobble fill maintained in its free-flowing porous state, and the upper portions of fill and top stone course removed and replaced with a pile assisted concrete roadway, essentially creating a bridge within a bridge.

This would achieve the following:

- Marginal improvement in water flow by creating funneling walls at the upstream side of the existing arch span.
- Improving roadway width and guardrails to Maine DOT standards.
- Providing full AASHTO HS20 live loading capacity.
- Maintaining the same overtopping flow dynamics as the existing bridge while additionally buttressing the structure to withstand such.
- Restoring and protecting the existing historic bridge in place, removing only the top course of masonry.
- Protecting and stabilizing the structure's internal structure from wheel loads and water ingress while providing a pathway for entrapped water to drain out.

This would be constructed as follows (please refer to Fig. A and B which graphically represent this scheme):

1. The present asphalt road surface would be removed along with the side rails and top course of stones from the side walls, which would be tagged, numbered, and stored. This lowering creates a plane to receive the concrete slab.

2. The top surface would be excavated an additional 2- to 3-feet down to the top of the cobble fill along the upstream side of the bridge, exposing the back surfaces of the sidewalls, which would be chinked and pointed. Stainless steel pins would be set into the backs of some of the stones. This depression becomes a lowered concrete haunch to help buttress the top of the upstream wall.

3. The bulged sections of the north face would be stabilized by localized injection grouting and pinning, chinking, and removal and re-setting, depending upon the severity and location of the condition. The inter-stone joints on the entire upstream wall surface would then be cut, re-chinked, and pointed.

4. The foundations of the abutment walls would be investigated and stabilized.

5. The tops of the walls would be evened off and re-set to create a uniform top edge that is approximately 10" to 12" below its present height.

6. The cobble fill would be excavated down to expose the top of the arch span and the fill on each side would be solidified with a low motility grout in order to stabilize it for drilling. A series of 2” to 3” diameter holes would be drilled through the grouted fill and into the stone headwalls, into which would be installed Cintec sock anchors that would extend from the sidewalls in a fan like pattern, up into the excavation.

7. Cone shaped depressions would be made in the cobble fill at about mid-distance on the embankment structures to each side of the arch span. These would later be filled with concrete to act as flared capitals or pile caps to support the roadway slab.

8. The inverts of the depressions would be gravity fed with a low-motility grout. This would help solidify the cobble fill to make it easier to drill mini piles.

9. Similar depressions would be created at the end of the span, but to a lower depth.

10. A total of 20 drilled mini piles would be placed within the excavated roadway. These would be of approximately 8” diameter and would pass through the stabilized cobbles and any underlying soil and down to bedrock. Two piles would support each of the abutments, five piles would support each of the intermediate capitals (four vertical, one battered), and three would pass through each of the headwalls below the arch.

11. All of the excavated depressions, along with the buttress at the back of the north wall, would receive reinforcing “cages” and concrete to create effective pile caps on which the concrete road span could be placed. The depression over the arch span would be additionally reinforced to stop its transverse spreading.

12. A 10” to 12” structural reinforced concrete slab and wearing surface would then be placed over the capitals, north side buttress, and the tops of the stone sidewalls and extended out by 4” to 6” to create a proper “drip”. Expansion joints would be incorporated over the intermediate capitals, and drained from below, and the slab surface would be given a gentle crown, for drainage off to the sides.

13. New Maine DOT approved wooden guardrails would be installed at each side.

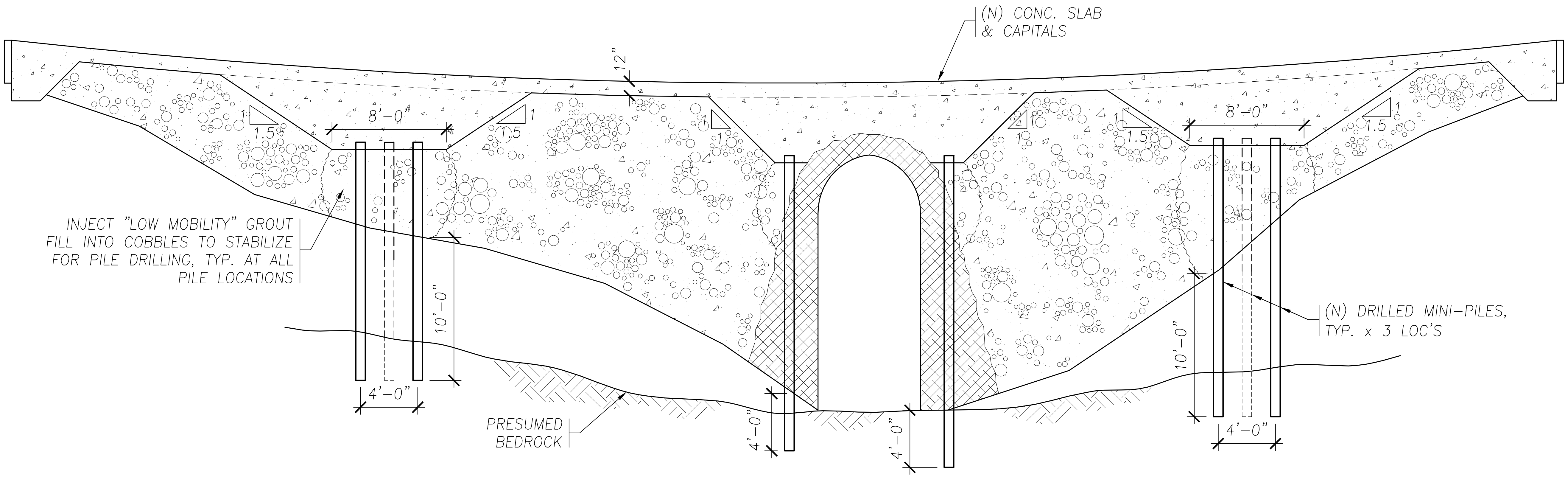
14. Stone rip-rap would be laid at the base of the downstream wall and training walls, would be added at the front of the arch span.

Estimated Cost for the Hybrid Scheme= $<u>1,390,000</u>. This cost is 7.5% higher than CLD’s replacement scheme, but preserves and protects the original historic structure and provides a new, full capacity roadway.

Thank you for the opportunity to provide this evaluation. Please contact me if you have any questions or would like further information.

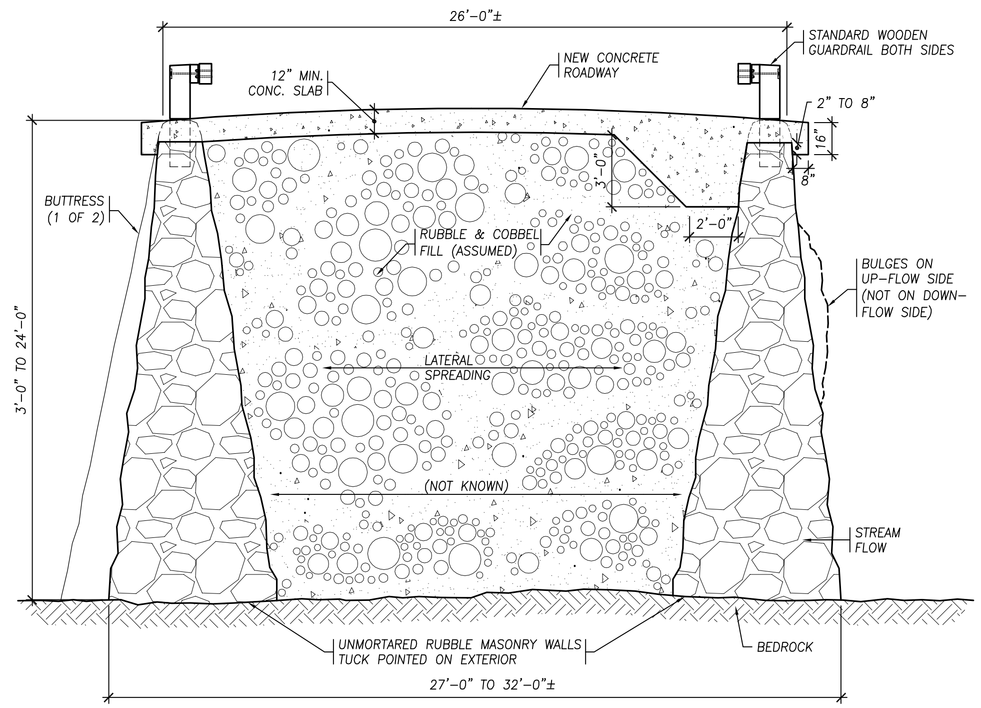
Respectfully Yours,

John M. Wathne, PE, President
Structures North Consulting Engineers, Inc.

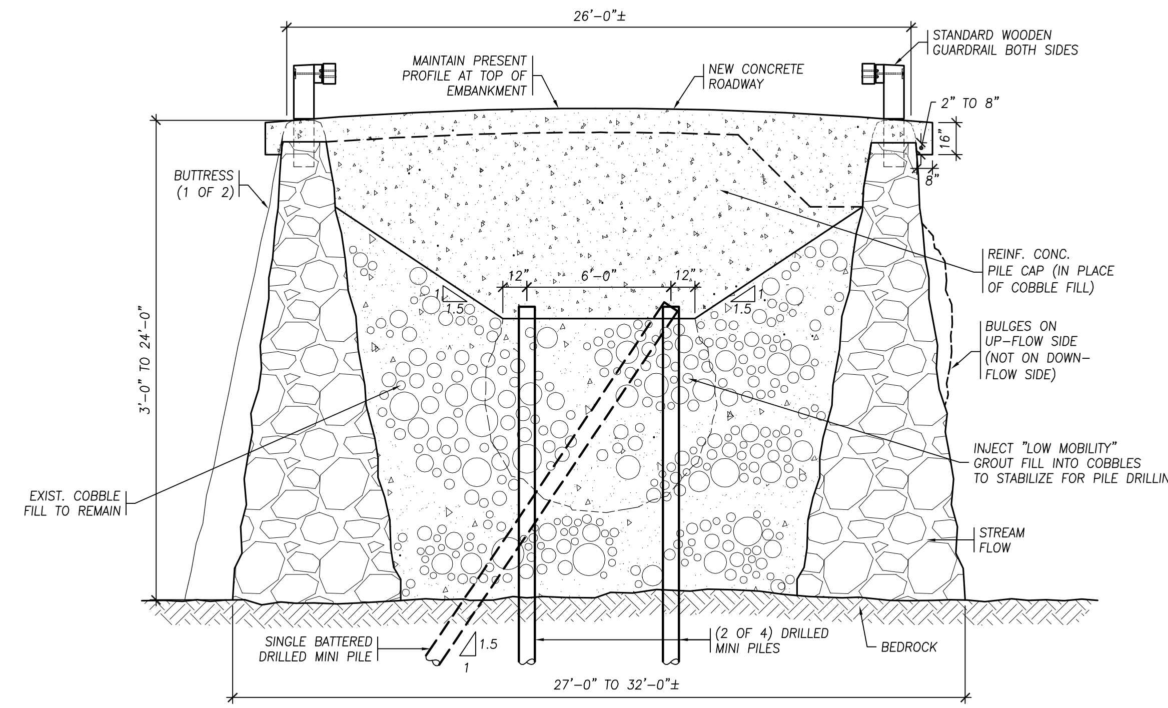


<u>FIG. A</u>: HYBRID SCHEME LONGITUDINAL SECTION

⅛" = 1'–0"



PROPOSED TRANSVERSE SECTION



TRANSVERSE SECTION AT MINI PILES

FIG. B: HYBRID SCHEME TRANSVERSE SECTIONS